LBNL-42767

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Mitigation Options in Forestry, Land-Use Change and Biomass Burning in Africa

Willy R.L. Makundi
Environmental Energy Technologies Division

May 1998

This work was supported by the U.S. Environmental Protection Agency through the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Disclaimer

MITIGATION OPTIONS IN FORESTRY, LAND-USE CHANGE AND BIOMASS BURNING IN AFRICA

Willy R. L. Makundi
Lawrence Berkeley National Laboratory

Abstract

Mitigation options to reduce greenhouse gas emissions and sequester carbon in land use sectors are describe in some detail. The paper highlights those options in the forestry sector, which are more relevant to different parts of Africa. It briefly outlines a bottom-up methodological framework for comprehensively assessing mitigation options in land use sectors. This method emphasizes the application of end-use demand projections to construct a baseline and mitigation scenarios and explicitly addresses the carbon storage potential on land and in wood products, as well as use of wood to substitute for fossil fuels. Cost-effectiveness indicators for ranking mitigation options are proposed, including those, which account for non-carbon monetary benefits such as those derived from forest products, as well as opportunity cost of pursuing specific mitigation option. The paper finally surveys the likely policies, barriers and incentives to implement such mitigation options in African countries.

1. Introduction

The biomass sector provides the most important near-term opportunities for reducing greenhouse gas (GHG) emissions and sequestering carbon in Africa. In this paper, we briefly describe assessment of mitigation options in forestry, agriculture and other land-use such as range and grasslands. Mitigation options as used here refer to those measures and policies which can lead to a reduction in the emission of greenhouse gases from the biomass sectors and/or through increased absorption and storage of carbon, both in perennial vegetation, detritus, soils, and in long-term biomass products. In most land- use changes involving decomposition and oxidation, GHG may be emitted. They include carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NO_x) and other non-methane hydrocarbons (NMHC). Although CO_2 forms the bulk of these gases emitted in the biomass sectors, it can be reabsorbed by vegetation via the process of photosynthesis and through organic matter replenishment in soils. On the other hand, the emitted trace gases accumulate in the atmosphere for their entire residence period.

It is estimated that net carbon emissions from the biomass sectors amount to 1.6 +- 1.0 billion tons per year, most of which originate from lower latitudes, and that forests from the mid and high latitudes have a net sequestration of 0.7 +/- 0.4 billion tons per year[1]. Africa's share of anthropogenic emission of greenhouse gases has been estimated at about 4% of global net emissions, adding to about 0.3 billion tons of carbon per year, mostly from forestry and land-use changes[2]. Despite the relatively low contribution to the atmospheric accumulation of GHG, Africa has a large potential of increasing the emissions from land-use changes due to persistent dependence on primary resources for subsistence farming and over dependence on biomass as a primary source of energy. The Zaire basin alone has a large reservoir of carbon estimated to exceed 20 billion tons. Under current or accelerated rate of depletion of the region's forests, most of this carbon can be released in a few decades. On the other hand, Africa has a large expanse of arable land, which could be used to undertake various mitigation measures intended to increase the stock of carbon stored on land.

The purpose of this paper is to examine the likely mitigation options in the biomass sector in the Africa region and briefly describe the approach used by the participating countries whose work is presented in this volume. The most applicable options for the region include forest protection and conservation, improved forest management, the use of improved cook stoves, short- and long-rotation forest plantations, agroforestry and natural regeneration, and the expanded use of sustainably procured timber and non-timber wood products. These options are described below in the context of their viability in the region. Finally, the paper briefly explores the policy instruments, incentives and barriers for implementation of such options in Africa.

2 Mitigation Options in the Biomass Sectors

The main purpose of forestry mitigation options is terrestrial carbon storage, which would reduce atmospheric accumulation and thus delay its impact on global climate. Mitigation options may be classified into three basic types[3]. One option is to **expand** vegetation stocks and the pool of carbon in wood products. Expansion will capture carbon from the atmosphere and maintain it on land over decades. The second option is to **maintain** carbon stocks in existing stands of trees and the proportion of forest products currently in use. Maintenance of existing stands, whether achieved through reduced deforestation, forest protection or through improved cook stoves, lengthens the duration the carbon stays trapped in woody vegetation. For example, tropical forest vegetation and soils contain 20-100 times the amount of carbon in crop and in pasturelands. Hence maintenance of these forests instead of converting them to croplands or pasture is an effective mitigation option, but difficult to implement, as long as the land is often more valuable deforested than forested[4].

A third avenue to reduce carbon emissions is to **substitute wood** obtained from sustainable sources **for other emission-intensive products,** particularly fossil fuels and unsustainably produced wood[5]. Fossil fuel substitution with biomass derived from sustainably managed renewable sources, will delay or avoid the release of carbon from the fossil fuel. This substitution also applies to products such as construction material of which production leads to substantial emissions. Cement and synthetic material are good examples.

2.1 Emission Reduction Options:

(i) *Forest Protection and Conservation*

These options protect the carbon and other GHG in both the vegetation and soil. Such measures will be in projects or initiatives, which are usually put in place for resource management purposes, often unrelated to carbon-emission considerations. There are opportunities in many African countries to establish or strengthen wildlife protection, soil conservation, water catchment preservation, and recreational reserves, which will also reduce eminent carbon emissions and sequester carbon if the biomass density increases. Measures to reduce losses from insects and diseases should also be considered under this category, although this may not be a priority option.

(ii) *Efficiency Improvements*

(a) Natural forest management such as emphasizing forest for multiple end-uses,

(b) Harvesting of natural forests which may involve increasing the capacity to utilize silviculturally optimum selective-harvesting regimes e.g. reduced impact logging. Measures to increase biomass extraction rates will reduce the amount of biomass left on site for decomposition.

(c) Undertake salvage operations during conversion of forests to other land uses like hydropower development, or road construction.

(d) Improvements in the product conversion and utilization efficiency can reduce emissions significantly. Such measures may involve technological intervention and will tend to find wide applicability in a region of which forest industries are dominated by mills which have a conversion efficiency of less than 25 percent in pitsawing and about 40 percent in conventional sawmills[6]. Improving various operational aspects of machinery and equipment in the wood industries may boost the amount of biomass converted to wood products by a significant proportion. Replacing the old generation of mills in the sector by a newer vintage can easily double the conversion efficiency in some cases. Installing capacities for residue utilization for bio-fuels and tertiary products also maximizes useful biomass utilization and reduces emissions.

(iii) *Bio-energy Initiatives*

These would tend to be attractive in a region of which about 75% of its primary energy demand is biomass based, with a few countries like Tanzania and Ethiopia exceeding 95 percent. The mitigation options in the bio-energy field will mainly reduce the use of biomass and thus maintain stocks of carbon, while refraining emission of trace GHGs. According to the revised IPCC methodology[7], all net emissions from biomass burning should be considered as loss of forest stocks. Options that can be considered here include:

(a) more efficient kilns for charcoal production and introduction of less wasteful charcoal packaging e.g. briquetting. The traditional charcoal kilns, which are widely used in the region, have an average efficiency of 20 percent, while the newer metal kilns average at about 30 percent[8]. Compared to efficient kilns used elsewhere, there is general consensus that charcoal production efficiency can be brought up to 50 percent in field conditions, a measure which will have a commensurate reduction of emissions.

(b) improved woodfuel stoves for firewood and charcoal for household and for small-scale industry such as pottery, restaurants, etc will cut emissions in proportion to the boost in efficiency. Studies done on dissemination of the Kenya Jiko and similar devices point out that with modest investment and strategically targeted programs, efficient stoves could replace most of the inefficient stoves in a decade or two[9].

(c) improved use of charcoal for industry such as steel production, as well as more efficient use of wood in agriculture such as in the curing of tobacco and tea.

(d) use of sustainably-grown biomass for fossil fuel substitution is a viable option in a few African countries where the use of fossil fuels is a large and growing share of the energy basket. South Africa and Zimbabwe are examples of countries, which could use this option to reduce their coal consumption.

(e) A major emission reduction option involves the use of sustainably grown wood e.g. woodfuel plantations, village woodlots, etc, to substitute for fuelwood from natural forests which are being depleted at an accelerated pace throughout the continent. For example, it is estimated that in 1990, Tanzania lost about 227,000 hectares of woodlands to production of charcoal and firewood[10].

(iv) Reducing emissions from land-use changes.

(a) Permanent intensive agriculture/pasture is a good long-term mitigation option to reduce emissions from land use changes that involve shifting agriculture or pasture. This requires investment in the necessary infrastructure and extension services necessary to convert shifting farmers/ranchers into sedentary land users. This option should be examined in the context of the respective country's rural development goals and policies.

(b) Supplementary economic activities for shifting farmers may boost their earnings and as such reduce their demand on forest land for subsistence. Measures which increase the opportunities for harvesting and marketing of non-timber forest products such as nuts, honey and fiber are good candidates. Also, introducing small-scale rural industries such as carpentry, brick making, weaving, etc may stem the rate of deforestation associated with subsistence farming. This option can not be treated in isolation from the country's rural development plans. However, within the development context, such an option should be very attractive.

(v) Wild-fire management

Since large areas of African savannas and woodlands are torched every year, management of these fires is an attractive option for reducing carbon and trace gas emissions. If one assumes that non-crown forest fires do not result into net carbon emissions, then the mitigation options to be considered for forest fires are those intended to avoid catastrophic fires that char woody biomass. The most applicable measure in the region would involve prescribed burning which regularly reduces the fuel load.

The biomass burning associated with annual vegetation like savannas emit trace gases such as CH4, N2O and NOx's. There are no obvious mitigation measures to reduce trace gases from savanna fires due to the fact that most of the fires are natural. Although burning biomass at a higher efficiency reduces the amount of trace gases emitted, the fire management techniques required given the size of savannas annually on fire, would tend to make this option of lower priority in the region.

(vi) Wildlife and range management

Mitigation options to reduce emissions from rangelands with wildlife or domesticated animals involve improved range management, wildfire prevention and control as well as good animal husbandry, including sustaining numbers which are within the carrying capacity of the range.

2.2 Options to Sequester Carbon.

Each one of the options under this category has to be separately identified and described depending on the end-use for which the new biomass is intended or depending on the fate of the new land use. These would include: forest products such as woodfuel, timber, pulp and paper; forest services like recreation, soil protection, emission reduction through fossil fuel substitution, etc. The fate of the biomass is critical in determining the carbon flows, cost and benefit streams, as well as the implementation possibilities of the specific mitigation option as listed below:

(*i) Afforestation* - Planting forests in bare land, with biomass density commensurate to the objective of the project. These options will be more acceptable if they correspond to the forest resource management aspirations of the country.

(ii) Reforestation - Replanting and/or natural regeneration of deforested or degraded lands will restock the area, and provide a future use of the forest in a more sustainable fashion, meanwhile sequestering carbon from the atmosphere. Enhanced regeneration can be considered here so as to increase the biomass density of understocked areas.

(iii) Agroforestry - The set of mitigation options that fall under this category will find favor with policy makers in many countries in Africa. It has been shown that this option is highly desirable for rural areas where it provides a variety of other goods and services, on top of being cost effective for carbon sequestration purposes[11]. Some or all of the agroforestry forms practiced in various areas may be applicable to different suitable sites in any given county in the region. The most commonly practiced forms are: (a) inter-cropping for the purpose of producing both agricultural and forest products, (b) boundary and contour planting for wind and soil protection, and for wood products, (c) taungya system applied as an integral part of forest management, in natural and plantation forestry, (d) pastro-silviculture for producing both forest and animal husbandry products, (e) non-timber tree farms such as those for rubber, tannins, bamboos, rattan, etc.

(iv) Urban and Community Forestry - here we include the additional biomass in non-contiguous tree cover such as residential shade trees, road side and demarcation trees in the rural areas, etc. Also to be considered is expanded urban forestry that sequesters carbon as well as reduces emissions through cooling and heating of urban residential and commercial buildings. This option is more attractive to those countries with a large urban population. Given current urbanization trends, many countries in the region will have a majority of their citizens in urban areas in the coming decade or so, and as such this option may be increasingly attractive.

(vi) Range and grasslands - options to sequester carbon in rangelands involve improved range management, especially biomass replenishment. In grasslands and rangelands, most of the carbon sequestration takes place below ground, and has a longer half life than carbon sequestered above ground[12]. These options would seem appropriate for the over-grazed areas of the rangelands of the west, east and southern Africa.

Each of the above options is influenced by broader cross-sectoral issues rooted in the country's land-use policy and law, which together with institutional arrangements are critical for the viability and implementation of any mitigation package. How each country chooses a set of mitigation options to consider for implementation depends on the results of thorough and systematic evaluation of all the major available options.

3 Evaluation of Mitigation Options

Past analyses of the costs, benefits, and economics of forest sector mitigation options have varied in the extent and treatment of components which should be included in mitigation assessment. The most commonly examined items include infrastructure and establishment costs, initial capital requirements, and the amount of GHG emission reduction. The more sophisticated studies have tried to look at the opportunity cost of land and growing stock, as well as total monetary benefits and costs. The less commonly included components in mitigation assessments are: non-monetizable costs and benefits, net present value (NPV) of finite or perpetual number of rotations, indirect impacts at local, regional, national and at international levels, as well as other environmental impacts such as bio-diversity. Here we briefly outline a recommended approach for mitigation assessment in land-use change sectors following Sathaye *et al* ,1995[13].

3.1 Summary of the Comprehensive Mitigation Assessment Process (COMAP)

The approach suggested here involves several steps. The first step involves a preliminary screening which is used to eliminate those options with least likelihood of implementation in the country for any number of reasons, including but not limited to; conformity with existing forest management plans, equity and co-benefits issues, feasibility and/or ease of implementation, or ecological soundness of the option. Two other criteria that need to carefully be consulted are *biophysical and political considerations.* On the first count, options may be screened out due to site specific biological or physiographic reasons such as climate, soil, drainage, altitude, etc. On the other hand, those options, which are expected to significantly infringe on the sovereignty of the country, or might tend to cause instability such as massive relocation of forest dependent populations, may be ruled out of consideration on political grounds. Given the delicate environment and socio-political climate in the region, it behooves African countries to carefully take such considerations into account.

After identifying the set of implementable options, one determines the forest and agricultural land area that might be available to meet current and future demand for wood products (both domestic and export) and services. Demand for wood products includes that for fuel wood, industrial wood products, construction timber, etc. Potentially surplus land in the future may be used solely for carbon sequestration or other environmental purposes. On the other hand, in many countries not enough land may be available, in which case some of the wood demand may have to be met through increased wood imports or through substitutes such as kerosene for woodfuel. Alternative combinations of future land use and wood product demand patterns will lead to different scenarios of the future. The most likely trends scenario is chosen as the baseline scenario, against which the others are compared.

The mitigation options are then matched with the types of future wood-products that will be demanded and with the type of land that will be available. This matching requires iterating between satisfying the demand for wood products and land availability considerations. Based on this information, the potential for carbon sequestration and the costs and benefits per hectare of each mitigation option are determined. The GHG flows and cost/benefit information are used to establish the cost-effectiveness of each option by use of a set of criteria such per unit area or ton of carbon. Such indicators include (i) initial cost, (ii) present value of cost, (iii) net present value and (iv) benefits of reducing atmospheric carbon. In addition, the information, in combination with land use scenarios, is used to estimate the total and average cost of carbon sequestration. Finally, the barriers, policies and incentives needed for the implementation of each scenario are explored.

Assessment of the macro-economic effects of each scenario, on employment, balance of payments, gross domestic product, capital investment, may be carried out using formal economic models or a simple assessment methodology

4 Mitigation Policies, Barriers and Incentives

4.1 Identifying Implementation Policies

Having constructed the baseline and mitigation scenarios, one has to identify and describe the policies, which may be necessary to implement the mitigation options. These policies can be divided into two groups: (1) biomass sector policies which govern the use of forest resources, and (2) non-biomass sector policies which happen to influence what happens in the biomass sector.

Biomass sector policies

The policies to be considered here are those which will either be used to maintain carbon stocks and/or expand carbon sinks. Such policies may include:

(i) Forest protection and conservation policies. Here one has to consider both national, regional and local measures to preserve existing vegetation cover. For example, local or national laws prohibiting conversion of steep slopes to agricultural lands, or gazetting vulnerable ecosystems into nature reserves.

(ii) Policies on shared responsibility for managing existing protected areas between local communities and the central agencies, which also include the sharing of benefits from the protected area tend to reduce "encroachment" by the surrounding population. Such policies have been applied effectively in many developing countries. A recent example is the shared wildlife management in Zimbabwe.

(iii) Policies governing terms of timber harvest concessions covering allowable cut, concession duration, levels and structures of fees and royalties will influence the implementation and effectiveness of the mitigation options in efficiency improvements. These policies may even include logging ban in specified ecosystems. Policies, which emphasize export of higher value timber products and ultimately a ban on log exports, may reduce the rate of forest degradation associated with the forest sector's contribution to the country's foreign exchange earnings.

(iv) Tax rebates and dissemination policies governing the adoption of efficient charcoal kilns and wood stoves have been shown to substantially affect success of such programs in the bio-energy field. The experiences of Kenya, Tanzania and Malawi are pertinent to these policies.

(v) Aggressive afforestation and reforestation policies both by villagers and forest departments will help expand the carbon sinks in the country, including incentives for private ownership of some forest resources.

Non-biomass sector policies

These policies are intended for the management of the other sectors of the economy, but have large influences on the depletion of the carbon stock, and at times may provide a disincentive to increasing forest and rangeland cover. The mitigation policies, which lie in this area, are:

(i) Land tenure policies that do not encourage private ownership of public lands with an express mandate to develop the land. Policies to the contrary have been shown to encourage wasteful conversion of forests to other land uses so as to meet the criteria for property rights assignment.

(ii) Land tenure policies that increase the certainty of tenure tend to make the owners of the land to plant and retain trees on their land. Such policies will be necessary in those mitigation options in agroforestry and of woodfuel plantations.

(iii) Agricultural policies, which do not encourage extensive and wasteful conversion of natural forests to agricultural lands. Policies which emphasize more intensive farming and conversion of less marginal woodlands tend to lead to production of the same agricultural output from less area, using the same amount of resources. To an extent, similar policies can selectively be applied to pasture management.

(iv) Infra-structural policies governing mining, dam construction, road construction can reduce unnecessary emissions.

(v) Taxes, credits, and pricing policies also play an important part In many African countries, the Stumpage price is too low to guarantee a supply of funds to reforest and manage the logging areas.

4.2 Barriers and Incentives for Implementation

The policies described in the last section may not easily be translated to mitigation programs/measures due to the existence of barriers and lack of incentives to implement them. A diverse array of criteria will have to be satisfied before a project can be implemented. The analyst should identify, describe and propose likely solutions to these barriers. The most common barriers to the implementation of biomass sector options can be divided into three categories:

(1) <u>Technical and Personnel Barriers</u>

- In most countries in Africa, the lack of scientific data on silvicultural, ecosystem management and pastoral practices, including soil conservation; is a serious impediment in evaluation and implementation of various options. This is a serious impediment in Africa. Availability of seed material, research on species provenance multi-cultural management including harvesting techniques, silvi-pastoral systems etc may be lacking for individual sites. Also, in the short to medium term, there may be a lack of qualified local personnel to carry out the projects as well as provide extension services necessary for the successful involvement of local populations.

(2) <u>Financial and Resource Barriers</u>

- Funding of forestry projects and rangeland management projects has been very low in most cases. Participation of the commercial sector may depend on availability of incentives for long term investment in the biomass sectors. The borrowing rates from banks may be too high for private investors and or local communities to get credit for these projects. Bilateral and foreign-source funds are restricted to those areas, which are more profitable, and as such there may not be enough funds for broad investment in the identified response options. Other sectors like agriculture may compete for labor with the above mentioned biomass sectors, depending on the types of crops and the seasonal demands on labor. Procedures and mechanisms for identifying of beneficiaries, cost-bearers and ways to apportion credit from the options may be a barrier to implementation.

(3) <u>Institutional and Policy Barriers</u>

Land tenure and land law may prove to be the strongest hindrance in implementing the mitigation options, especially in this region where land and politics are so intertwined. Also, institutions necessary to allow for participation of various parties in the options may not exist in the country. For example, there may not be a mechanism for sharing benefits between the central authorities and the local participants in community-based mitigation options. Policy barriers to harvesting, marketing of forest products, pricing, tariffs and quotas for exports and imports may also hinder implementation of some of the mitigation options.

The scenarios provide useful information to policy-makers regarding the total and average cost to sequester carbon. However, this information is not adequate to develop policies and measures to implement climate change mitigation projects. A diverse array of criteria will have to be satisfied before a project can be implemented. These may include the ease of implementation, identification of the project's beneficiaries and losers, together with institutional and legal considerations.

5. Conclusions

This paper lists the mitigation options in forestry, land-use change and biomass burning as relevant to African countries. It briefly describes a bottom-up methodological framework for assessing mitigation options that include the use of specific cost effectiveness indicators for ranking mitigation options. The approach pays explicit attention to non-carbon monetary benefits, like those derived from forest products, which may completely offset a project's cost and the opportunity costs of pursuing forestry options. The paper finally surveys the likely policies, barriers and incentives to implement such mitigation options in the region.

REFERENCES

1. IPCC. 1995. Climate Change. Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses. Cambridge University Press, London.

2. Okoth-Ogendo H. and J. Ojwang. 1995. A climate for Development: Climate Change Policy Options for Africa. ATS Press, Nairobi, Kenya and SEI, Stockholm, Sweden.

3.Brown S., Sathaye J., Cannell M., Kauppi P., Hueveldop J., Weyers S. and Singh N. Chapter II. Management of Forests for Mitigation of Climate Change. Working Group II, IPCC 1995 Assessment.

4.Gillis M. and Repetto R. 1988. Deforestation and Government Policy, International Center for Economic Growth, Occasional Papers No. 8, Cambridge University Press.

5. Hall D., Mynick H. and Williams R. (1991). Cooling the Greenhouse with Bioenergy. Nature, Vol. 353, Sept. 5, pp.11-12.

6. Solberg B. 1988. Choice of Technology in Less Industrialized Countries with Particular Reference to Forestry and Sawmilling. Report No. 3, Aas-NLH, Norway.

7. Intergovernmental Panel for Climate Change (IPCC). 1996. Revised Guidelines for National Greenhouse Gas Inventories. OECD, Paris.

8. Sawe, E. and G. Leach. 1989. Tropical Forestry Action Plan, Tanzania: 1990/91 - 2007/08; Bioenergy

Chapter. MNRT, Dar-es-Salaam, Tanzania.

9. Karekezi, S. and G. Mackenzie.1994. Energy Options for Africa: Environmentally Sustainable Alternatives. UNEP CEEE.

10. Makundi W.R. and A. Okiting'ati. 1995. Carbon Flows and Economic Evaluation of Mitigation Options in Tanzania's Forest Sector. *Biomass and Bioenergy*, Vol. 8, No 5.

11. Makundi, W.R. 1994. Forestry and Energy Production in the Tropical Drylands: The Case of Sub-Saharan Africa. In: Proceedings of the Conference on Human Livelihoods in Drylands: Constraints and Possibilities. Held in Sigtuna, Sweden, Nov 1993. SAREC

12. Scholes, R.J. 1995. Greenhouse Gas Emissions from Vegetation Fires in Southern Africa. In: African GHG Emission Inventories and Mitigation Options, *Eds*. J.F. Fitzgerald *et al.* Kluwer Academic Publishers.

13. Sathaye, J., W. Makundi and K. Anoraks. 1995. Comprehensive Mitigation Assessment Process (COMAP). In *Biomass and Bioenergy*, Vol. 8, No. 5.